Paleoclimatic reconstruction of the Atacama Desert (18-26 S): Evidence from paleowetland deposits

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Abstract

Over the last three years we have been mapping and dating paleowetland deposits between 18-26S in the Atacama Desert, Chile. We use these deposits, which are found around springs, low-energy streams, and within dry stream channels, to reconstruct paleo-water tables and past ground-water discharge. A distinct advantage of these deposits is that they contain an abundance of terrestrial organic matter and can be easily C dated, thereby circumventing problems caused by C reservoir effects. Ground-water budgets associated with these systems are tied to precipitation and recharge rates in the central Andes (>4000m), and therefore these deposits can be used to reconstruct late Quaternary paleohydrology of the central Andes. Here we provide a synopsis and comparison of ground-water levels along a north-south transect in the Atacama.

Introduction

Late Quaternary pluvial periods in the central Andes enabled lakes to grow, glaciers to advance, and vegetation to expand downslope into areas now too arid to support vascular plants. These past increases in precipitation also influenced rates of ground-water recharge in the central Andes, the height of local ground-water aquifers, and the amount of discharge where ground water intersects the land surface. In this study, we track changes within these ground-water systems by mapping and dating paleowetland deposits to track sustained hydrologic changes in the central Andes.

Study Areas

Data presented here are from 8 separate hydrologic systems from the northern Atacama: 1) Zapahuita Springs (3500m, 18.3 S, 69.5 W), 2) Quebrada la Higuera (3500m, 18.7 S, 69.5 W), 3) Quebrada Tana (1200 m, 19.5 S, 70 W), 4) Quebrada Guataguata (2050m, 20.1 S, 69.3 W), the central Atacama: 5) Rio Loa (2500m, ~21-22 S, 68.5-69.5W), 6) Rio Salado (2500m, 22.3 S, 68.5W), 7) Tilomonte Springs (~2500m, 23.8 S, 68.1W), and the southern Atacama: 8) Quebrada Chaco (2650-3350m, 25.4 S, 69-69.5W) (Figure 1). These study areas include point source springs (1, 7), low-energy perennial streams that intersect the water table (3,4, 5, 6, 7), and ephemeral streams that do not intersect the modern water-table (2, 8).

Methodology

Paleowetland deposits generally consist of fining upward sequences of sand, silt, tufa ($CaCO_3$), sinter (SiO_2), diatomite, and organic mats. The presence of these latter, paludal sediments, indicate perennial water and are used in this study to reconstruct the past height of local water tables.

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Because these hydrologic settings are not closed basins, an increase in water table height must be supported by an increase in ground-water discharge. The concordance of results from a variety of hydrologic settings suggest that response times within these systems are minimal and that these systems are responding to a regional mechanism, climate.

Results

Paleowetland deposits of similar ages were found within our study areas. We divided these paleowetland deposits into the following time-stratigraphic units:

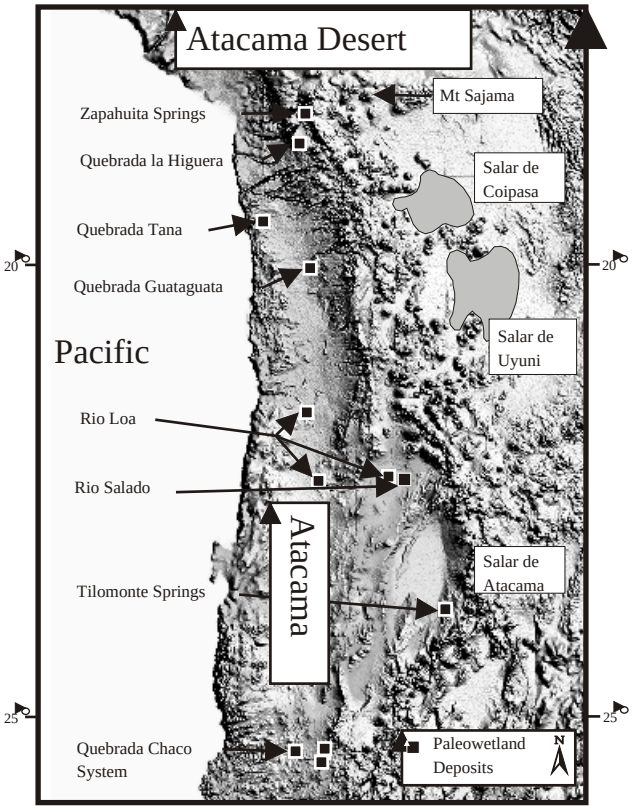

Figure 1 Location of Atacama paleowetland deposits from this study and some other important proxy records from the Central Andes.

Unit A (>44 ka B.P.), Unit B >15.4-9 ka B.P., Unit C (8-3 ka B.P.), Unit D (3-1.7 ka B.P.), and Unit D_2 (<1.0-0.2 ka B.P.) (Figure 2). Each of these units represents a period of higher water tables than today, and were terminated by a drop in the water table and incision of paleowetland deposits.

Unit A Unit A deposits are present at locations 5 and 6 in the central Atacama and are beyond the age of ^{14}C dating. At each of these locations the deposits are ~20m above modern wetlands and represent the hi ghest paleo-water table.

Unit B Unit B deposits record the late Glacial/early Holocene wet phase in the Atacama and are present at localities 1, 7, and 8. At each of these locations these deposits represent the highest paleo-water table. At locality 1, the base of these deposits have yet to be dated but water tables were high between >11.2-9.5 ka B.P. and then drop rapidly after 9.5 ka B.P. At locality 7, Unit B deposits date from 15.4-9.0 ka B.P. At locality 8 in the southern Atacama, Unit B depos its range in age from 20.9-10.7 ka B.P.

Unit C Unit C deposits represent a mid-Holocene wet phase in the Atacama dating from 8.0-3.0 ka B.P. The age of Unit C deposits at individual localities are as follows:

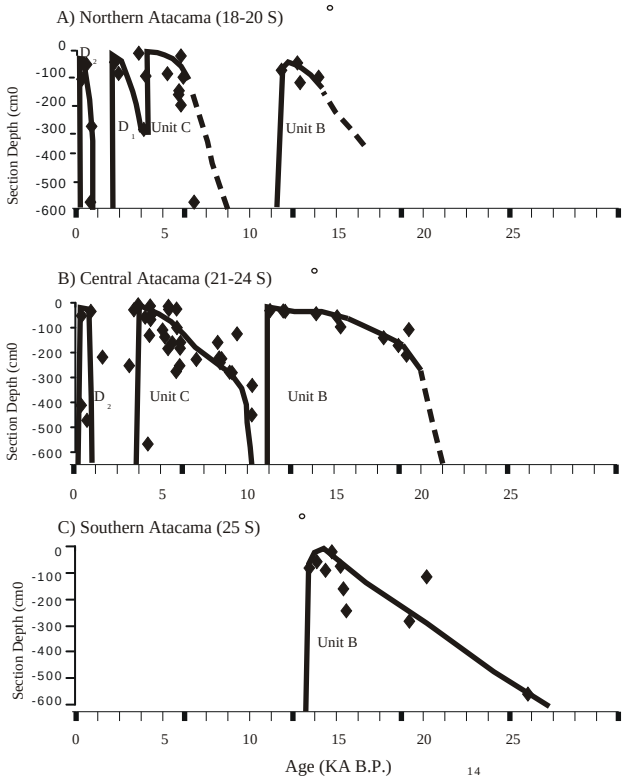

Figure 2 Distribution of calibrated C ages from organic mats within paleowetland deposits versus depth in section. Diamonds represent individual calibrated C ages while lines represent episodes of water table rises. Figure does not portray relative height of different episodes of water table rise.

Location 1 (4.9-2.8 ka B.P.), Location 3(>5.4-4.9 ka B.P.), Location 4 (1 date 4.8 ka B.P.), Location 5 (4.3-3.0 ka B.P.), Location 6 (>6.7-4.3 ka B.P.), Location 7 (8.0-3.0 ka B.P.). Mid-Holocene paleowetland deposits of similar age are also located at Quebrada Puripica (6.5-3.0 ka B.P.)(Grosjean et al., 1997) and Quebrada de los Burros, Corral section (8.0-3.4 ka B.P.)(Fontugne et al. 1999). The water table drop at most of these locations occurs around 3.0 ka B.P., however it occurs from 150 0 to1000 years earlier at location 3,4, and 6.

Unit D Unit D deposits represent a minor water-table rise during the late Holocene. At locations 2, 3, 5,and 7, this water table rise (Unit D) has been dated to between 1.0-0.2 ka B.P. At location 2, however, the late Holocene unit dates from 3.1-1.7 ka B.P.(Unit D). This is the only location to date where we have found this unit. Therefore, before attributing a climatic forcing to this unit, it needs to be documented at other locations.

Summary and Conclusion

Our results indicate the following scenario for late Quaternary paleohydrology in the Atacama Desert: The late Glacial/early Holocene (LG/EH) wet period dates from >15.4 ka B.P. to between 10-9 ka B.P. This episode represents the wettest period in the Atacama over the last 40,000 years, and agrees well with other paleoclimatic records in the region (Geyh et al., 1999; Betancourt et al. 2000). The early age (20.9 ka B.P.) for the beginning of this wet phase in the southern Atacama may be due to the influence of the Westerlies during the LGM. The LG/EH wet period was terminated by a significant drop in water tables between ~9-8 ka B.P. During the mid-Holocene, water tables rose again, yet to lower levels than during the LG/EH, reaching maximum heights between 5-3 ka B.P. This evidence for a wet mid-Holocene contradicts previous assertions of a dry mid-Holocene in the region. The late Holocene (3-0 ka B.P.) is characterized by low water-tables with one very minor water-table rise w ithin the last 1,000 years.

We argue that these fluctuations in the paleohydrology of the Atacama Desert are directly linked to sustained changes in precipitation in the central Andes. These changes do not support local summer insolation forcing over South America. Instead, our records indicate the possible influence of northern Hemisphere teleconnections or non-linear insolation forcing over the tropical Pacific.

References

Betancourt et al., 2000, Science 289: 1542-1546

Fontugne et al., 1999, Quaternary Research 52:171-179

Geyh et al, 1999, Quaternary Research 52:143-153